**Persistence in aerospace engineering: Why students choose and leave aerospace engineering**

by

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## DEDICATION

I dedicate this work to my family, especially my parents, sister and grandma. To my parents, Carlos and Margarida, for their unwavering support and commitment to helping me succeed in life. Thank you for asking "How's the thesis?" every day for three months and laughing nervously every time I said "almost done". To my sister, Ines, for being such a great inspiration to me, teaching me to be brave and determined. And to my grandma, Zé, for keeping me grounded and calling me every single day even if just to say goodnight.

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## ABSTRACT

Technological development, research and progress are one of the boosters of the US economy. Preparing students is important for the advance of the US economy and quality of life. STEM (science, technology, engineering and mathematics) degrees prepare students for the technological and economic challenges by providing them with tools to advance in these areas. However, the decline in enrollment in engineering degrees and a low retention rate may be hindering the US's ability to respond to their technological and economic challenges. It is then important to increase the retention of students in STEM and engineering.

Despite several studies on persistence in STEM and engineering, there are very few studies on persistence in aerospace engineering, most specifically on why students choose and leave aerospace engineering. Aerospace engineering has specific challenges that are not addressed in studies of other engineering fields, such as the whimsical nature of space and flight, the perceived number of jobs in the space industry, the specialization of aerospace engineers and others.

Our research investigates the reasons why students choose and why students leave aerospace engineering. Through a survey administered to students who declared as aerospace engineering students, we found students' main reason for choosing aerospace engineering is a long term passion for the field, which in many cases starts developing during childhood, and carries into their college major choice. However, during their academic career, some students will not persist in aerospace engineering, with 23% of the respondents of our survey having changed major. Students' main reasons for leaving aerospace engineering are their mismatched expectations between job prospects when they make their major choice and when they become aware of the reality of the job market, high specialization in comparison to other engineering

fields, as well as poor teaching and advising.

To improve persistence in aerospace engineering, both the program and the students can make changes. Programs should aim to improve the quality of their teaching and advising, as well as showcase the field and its job opportunities realistically. Students should research their future major and understand its job market, as well as the implications of choosing a highly specialized field.

# CHAPTER 1. INTRODUCTION

The aerospace and defense industry are essential for U.S. economy, accounting for 6.1% of all value generated in U.S. manufacturing sector in 2015 (Aerospace Industries Association). Highly skilled workers are needed to support manufacturing, especially considering the projected economic growth in the U.S. economy and baby boomer retirements. In a report published by Deloitte, titled “The skills gap in U.S. manufacturing, 2015 and beyond”, it is stated that predictions for the next decade indicate 3.5 million jobs will need to be filed in manufacturing, but 2 million of those are likely to go unfilled due to the skills gap between prospective employees and job skills needed (Deloitte, 2015).

In another report published by John F Sargent Jr. for members and committees of congress, entitled The U.S. Science and Engineering Workforce: Recent, Current, and Projected Employment, Wages, and Unemployment, Sargent says there may be shortages of skilled labor in some industries, including new and emerging fields such as nanotechnology as well as cyclical industries, including aerospace (Sargent, 2017). It is then important to understand why students choose engineering, and more specifically aerospace engineering, and why students leave the field. This understanding will help address the underlying issues behind low retention rates in aerospace engineering and make changes to help students complete their degrees and enter the workforce with the skills needed to help advancement and progress.

In 2017, according to numbers reported by the ASEE (American Society of Engineering Education), 124,477 engineering degrees were conferred, with 3.25% of those being awarded in Aerospace Engineering. Additionally, from 2008 to 2017, full time undergraduate aerospace enrollment grew from 17,561 to 23,756, a growth of 35%. However, the increase in aerospace enrollment lags the increase for other engineering disciplines, which went from 403,191 in 2008 to 619,095 in 2017, an increase of 54% (Yoder, 2017).

For example, out of all students enrolled in engineering, from data collected in the MIDFIELD (Multiple-Institution Database for Investigating Engineering Longitudinal Development) study, 11.1% are enrolled in aerospace engineering. Of all students enrolled in Aerospace engineering, 37.6% graduated in Aerospace engineering within 6 years, which lags other disciplines where this rate is higher for graduation within 6 years. These findings were discussed by Orr et al. (2015) on a study conducted at six MIDFIELD universities between the years 1987 and 2010. The study aimed to understand the ethnic/racial and gender distribution of students who choose aerospace engineering and students who left aerospace engineering. It shows that Hispanics and whites are more likely to choose aerospace engineering among all engineering disciplines, while Asian and Black students are less likely to choose aerospace. Conclusions for the study show that black students are less likely to persist in aerospace engineering than any other ethnicity/race and it also shows that the 6-year graduation rate for aerospace engineering is lower than other engineering disciplines.

In a discussion of persistence, it is important that we first define what it is in the context of this work. Persistence, attrition and retention are often used interchangeably, however, different authors define them differently. Tseng, Chen and Sheppard (2011) use persistence and retention interchangeably, further defining academic persistence as the intention to complete an engineering major and professional practice persistence as the intention of becoming a practicing engineer. Eris et al. (2005) use the terms academic persistence and professional persistence, identifying a timeframe for professional persistence as the intention to exercise as an engineer for at least three years after graduating with a bachelor’s degree. Cech et al. (2011) in their paper on gendered persistence in engineering define behavioral persistence as the intent to study engineering from freshman to senior year, and intentional persistence as the intent to practice engineering after graduation. Given the many different definitions of persistence, we will use academic persistence to refer to the students' intent to continue enrollment in engineering and professional persistence to refer to the students' intent to pursue a career in engineering.

Persistence in STEM and engineering has been investigated in several studies (Seymour and Hewitt, 1997, Matusovich et al., 2010, Watson et al. 2015, Wang, 2013), but there are few studies that identify the reasons why students choose Aerospace Engineering in college. Aerospace engineering offers different challenges to those presented by other disciplines, including the reason mentioned by Seymour and Hewitt who reported that some of the students making under informed choices by choosing a major did so based on childhood dreams, with the reported fields being, among others, space exploration, flying, or aerospace design. (Seymour and Hewitt, 1997)

Seymour and Hewitt (1997) reported on reasons for students choosing STEM majors, on a three-year study with 335 students from seven institutions. Data was collected by personal interviews as well as focus groups of three to five members. The top reasons for choosing STEM were intrinsic interest, meaning interest in the field or career provided by the major; active influence of others, defined as a choice influenced by someone close to the students, including parents or other family members; and pragmatism/materialism, such as high salaries and prestigious career paths.

Seymour and Hewitt's (1997) study includes STEM majors, including those in the biological sciences, physical sciences and mathematics as well as engineering. However, it is important to understand engineering students' reasons for choosing engineering, as engineering poses different challenges to those in other STEM majors, including the perception engineering is a “harder” major (Kennedy, Hefferon and Funk, 2018), as well as intrinsic behavioral reasons such as liking to build or design structures and being “interesting”.

Of the studies that focus on engineering, Watson et al. (2015), considered the reasons why students chose engineering in a study using a survey and open-ended questions administered to civil engineering students. In this study 45% of the students identified behavioral reasons, defined as the desire to do something like building or solving problems, the second reason was the challenging nature of engineering majors and the third reason was psychological, defined as enjoying or liking engineering. Watson et al. concluded in their study that retention was not dependent on a student’s reason for choosing engineering. This conclusion is not in concordance with the conclusion from Seymour and Hewitt, who found links between a student’s reason to choose a STEM major and their persistence in that major.

The conclusions from Watson et al. (2015) are also not in consonance with Matusovich et al. (2010), who also studied the reasons of why student choose engineering, using motivation theory and building on the work of Seymour and Hewitt (1997). Using semi-structured interviews with 11 students over a period of four years, Matusovich el al. (2010) found that students choice when selecting engineering and persisting in the major are related to students attainment value, specifically how the outcome of a task reflects on the student and their sense of self, and less related to students interest. Despite not providing specific reasons as do Seymour and Hewitt, Matusovich’s work shows a connection between students’ reason for choosing engineering unlike Watson’s. Investigating why students choose engineering before they enroll in college seems to be one of the predictors of their persistence in the major. However, it is important to understand what other factors influence student’s persistence.

Sheppard et al. (2010) identify further reasons for why students choose engineering, in the report for the APPLES (Academic Pathways of People Learning Engineering Survey) survey. The APPLES survey was applied at 21 U.S. engineering schools in 2008, for a total of 4266 students. Discussing what motivates seniors in engineering to choose engineering, the number one reason is intrinsic psychological motivation (motivation to study engineering for its own enjoyment), the second is intrinsic behavioral (motivation to study engineering for practical and hands-on activities) and the third is social good. Other reasons are financial motivation, mentor influence and parental influence. Comparing motivations for senior-level students and first-year students to study engineering, the authors conclude those motivations seem to emerge before the college experience and are reinforced during student's higher education experience. In this study, beside the influence of pre-college reasons to choose engineering on persistence, Sheppard et al. also speak about the college experience, which includes interaction with faculty inside and outside the classroom, exposure to project-based learning and academic involvement (attending classes, submitting work on time), as having an influence on persistence. These two stages of students' academic lives should be investigated to get a bigger picture of persistence predictors.

In one of the few studies including exclusively aerospace engineering students, Grimes et al. (2018) reported on factors contributing to student retention, in a mixed-methods study at Mississippi State University. The authors used the study to validate their conceptual framework, a framework that integrates Erikson's Identity Theory and Bandura's self-efficacy theory and suggests a theoretical framework for success. The suggested theory integrates community engagement, academic achievement and intention to persist, along with Bandura's and Erikson's theories and relates these factors with background factors to predict student retention in engineering. The results of this study indicated that students' main reasons to join aerospace engineering were mentor influence, fascination with flight and airplanes, pre-college experiences, STEM high school classes and future applications, mostly the prospective of jobs in the space industry. These reasons align with reasons reported for choosing other engineering majors and indicate new reasons that may be exclusive to aerospace engineering students, such as the prospective of jobs in the space industry. Grimes et al. (2018) also reported on the retention of students in aerospace engineering, and out of the 98 students surveyed, 26 (27%) were not retained. However, the study fails to identify the reasons why students leave aerospace engineering. The study by Grimes also lacks by having a small sample size due to being conducted at a university with a small graduating class.

Of the reasons why students choose aerospace engineering, there are a few reasons that were unique to the aerospace field, which may indicate that aerospace engineering also presents unique reasons for why students leave aerospace engineering. That is one of the shortfalls of the findings reported by Grimes et al. (2018) is that, despite reporting on the retention rate for aerospace engineering students, it fails to identify the reasons why these students changed majors. In fact, there isn't much literature on why students leave aerospace engineering, which is one of the questions that must be addressed to understand low retention. In other studies, conducted in STEM majors and engineering, different reasons for leaving were found.

Seymour and Hewitt (1997) reported on why STEM students leave STEM, including loss of interest for STEM, poor teaching by STEM faculty, poor advising or help with academic problems, and overwhelming curriculum, among others. Additionally, for engineering students, disappointment with the field is one of the top reasons why students drop out.

Eris et al. (2005) conducted a longitudinal study on persistence in engineering, by using the PIE (Persistence in Engineering) survey, to understand the correlation between persistence in engineering education and professional engineering practice. The study was administered during 7 semesters to 160 students enrolled in engineering degrees, of which 141 were considered in this study, and of those 141, 107 persisted in engineering (75%). The study identifies some differences between persisters and non-persisters, showing that parental influence is more common among non-persisters and high school mentor influence is more common among persisters. Additionally, non-persisters seem to be less confident in their math and science skill. Another predictor of persistence in engineering is the students' self-perception of their ability to graduate, with non-persisters having less confidence in their ability to graduate. Other factors studied were not significant in predicting persistence in engineering. Persistence numbers are similar to those reported by Grimes et al in her study, where the retention rate was reported at 74% (Grimes et al, 2018).

In a six-year longitudinal study of undergraduate women in engineering, Brainard and Carlin (1998) looked at the factors that influence retention of women in engineering. In their study, with 672 participants, surveys and interviews were used for data gathering, at all levels of schooling, from freshmen to seniors. Students who do not persist in engineering leave mainly due to losing interest in science/engineering, wanted to enroll in another field and discouraging academic difficulties, poor teaching and the low reward for high effort perception of engineering. Students are more likely to switch majors during their freshmen and sophomore year. Conclusions for this study detail persistence factors for all level of study, which change with student's classification. For freshmen (retention rate of 91%), enjoying math and science classes is a major persistence factors, which can also be seen in persistence for sophomores (retention rate of 73%) and juniors (retention rate of 65%), whereas in senior's (retention rate of 59%) major persistence factors are the teaching quality and attending conferences and events. Some of the themes found in this study for why students leave are also identified in other studies, including the one by Seymour and Hewitt, which may help in generalizing the findings in this study despite its focus on women's experience in engineering.

Besides these conclusions, Marra et al. (2012) detailed further reasons for why students leave engineering. Survey data was collected from students who had recently changed from their engineering major to another major, with results saying there are both academic and non-academic reasons factored into students' choices. Academic reasons included a difficult curriculum, as well as poor teaching and advising, and non-academic reasons included lack of belonging, which the authors concluded was the most important factors weighing on the student's decision. One particular conclusion for this study was the authors did not see a correlation between gender and persistence but did see a correlation between minority status and persistence.

Other studies, including Meyer and Marx (2016) and Fleming et al. (2006) also identify poor advising and poor teaching as reasons why students don't persist in engineering, as well as lack of sense of belonging and motivation.

We can find both individual as well as institutional factors for why students leave engineering. These factors are seen in engineering in general, but as we saw previously with the reasons for why students choose aerospace engineering, there may be unique reasons for why they leave aerospace engineering that should be investigated.

To improve retention rates in aerospace engineering it is important to understand why students aren't persisting in this field. By addressing the issues responsible for the low retention rates, we may see an increase in students completing their aerospace engineering degree and entering the work force.

To learn why students choose and leave engineering we surveyed undergraduate aerospace engineering students at an intensive research institution in the Midwest and asked them why they chose aerospace engineering, and for the students who did not persist, why they left aerospace engineering among others. To interpret the results, we used Weidman's theory of socialization.

## Theoretical Framework

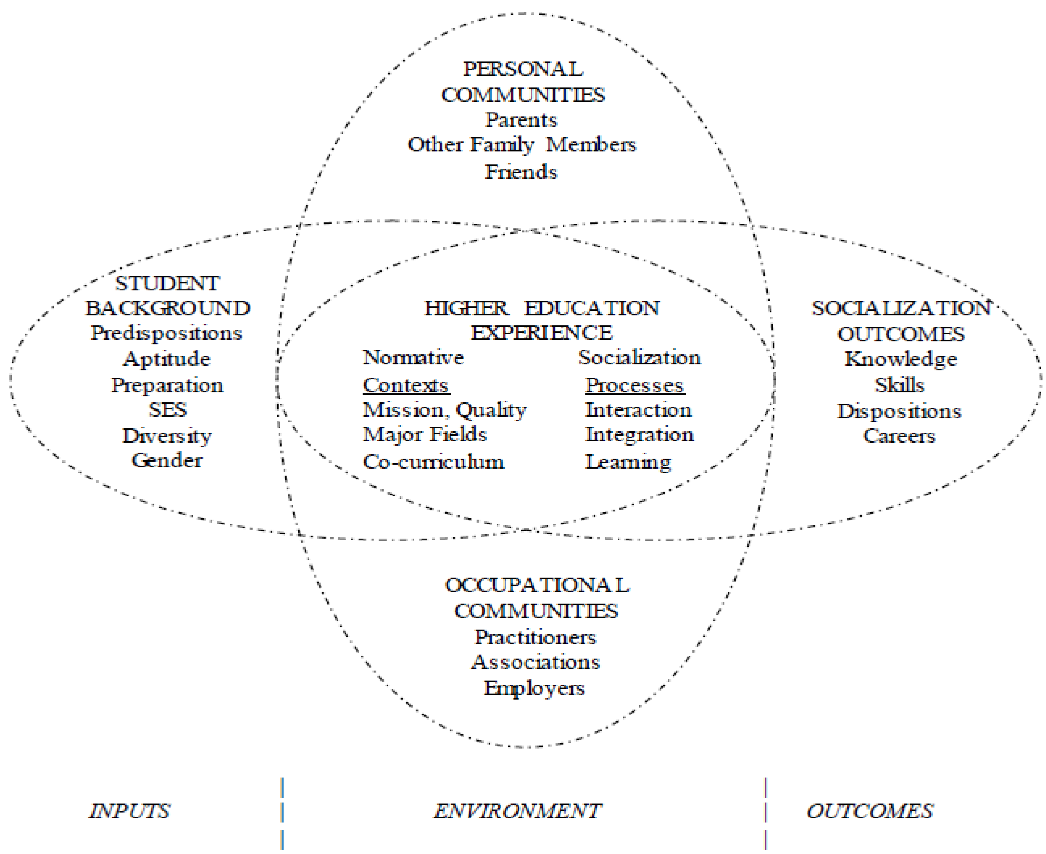


Figure 1. Undergraduate Socialization model adapted from Weidman's undergraduate socialization (1989, 2006, and 2014)

Several models have been developed to predict student persistence in college. Among those models are Tinto's Student Success Model (1975), Astin's Input-Environment-Output model (1977, 1984) and most recently, Terenzini and Reason's (2005) College Impact Model. Weidman's (1989) framework of undergraduate socialization has also been used to predict student persistence in college (Titus 2004) and STEM (Espinosa 2011, Eagen et al 2013, Johnson 2012).

Weidman's framework was selected for the interpretation of results in this study for its well defined categories (Weidman 1989, 2001, 2006 and 2014), as well as the fact the model accounts for several factors before and during college enrollment, with both stages having been shown to have an impact on persistence (Seymour and Hewitt, 1997, Grimes, 2018, Eris et al., 2005). Well defined categories eliminate, in this case, the bias introduced in the interpretation of vaguely defined categories. Weidman's model is also one of the few that explicitly takes into account academic environments such as departments (Feldman et al., 2004).

Weidman's conceptual framework is based upon his own work as well as the work of Chickering (1969), Tinto (1975, 1987), and Astin (1977, 1984). Astin's influence on Weidman's revisited model (Weidman 2014) can be seen on his model (figure 1), where Weidman identifies the input, environment and outcomes sections according to Astin's work. This framework models and aims to understand socialization in college, both personal and institutional. Institutional socialization accounts for the interactions between students and faculty, administrators, staff and occupational communities, while personal socialization accounts for the interactions between peers, family and friends.

The framework takes into consideration the students' background characteristics, non-college influences, and higher education experience to explain students' outcomes. The framework is then the process by which students enter college with certain aptitudes, predispositions and other background characteristics, and through the influence of their higher education experience, personal and occupational communities are influenced, either to reinforce or counteract, in their values and aspirations, knowledge and skills. These represent socialization outcomes. In the model, dotted lines are used to indicate that categories are not strictly belonging to one category. The horizontal organization indicates processes that are consecutive, while the vertical organization indicates processes that are concurrent.

The model input are the student background characteristics: socio-economic status, which can be expressed by the students' parents' education level, annual income or educational prestige; aptitude, which is best characterized by students' performance in standardized tests; diversity, including women and people of color; gender; preparation, meaning academic preparation; and predispositions, which may include values, career aspirations, learning styles, beliefs and others.

Environment includes students' higher education experience, personal communities and occupational communities. The verticality of personal and occupational communities on the model indicates these influences are not part of the college experience but rather exterior influences.

Personal communities constitute the group of personal influences that include friends and family, through different means of contact including social media, home visits or vacations. These communities also account for the importance of parental influence in students' decisions, whether that is recognized by the student or not. These influences become less relevant as students' progress through college, especially for students who have left the home to attend college.

Occupational communities constitute the group of career-related influences that include employers and associations, as well as internships and cooperative learning, and the set of careers that require specialization through higher education. Employers, accreditation agencies and professional associations are organisms that may have influence on the curriculum; accreditation agencies through their set standards; professional associations through licensure exams which universities prepare students for; and employers through industry advisory councils.

Within higher education experience students are exposed to normative contexts, including expectations of faculty and staff, and socialization processes, processes by which each individual is exposed to different beliefs and values. The level of acceptance to those different beliefs and values by each individual is called social integration.

The normative context includes the institutions expectations on students and their values influence students' values. One of the representations of the institutions values is stated in their mission, where the institution states its purpose, which also motivates resource allocation. The institutions quality is also a part of normative contexts and can be assessed by resource allocation and institutional reputation including Carnegie classifications. These factors may also influence students to choose a particular college for their resources, especially prospective careers. One example could be a student choosing a religiously affiliated college, which may allow for a more personal interaction between students and faculty due to its small population size. Additionally, students are influenced by their academic department, which includes faculty, size of the institution, and represents the institutions mission. Faculty have a large influence on students, both through evaluations and social interactions. Also important are the co-curricular activities.

When it comes to socialization processes, we assume that more frequent and more intense relationships are more influential on a student than others. Interaction characterizes students' interpersonal relationships with peers and faculty outside the classroom. These interactions can happen at such places as restaurants, coffee shops and residence halls. Those relationships become more influential with the increase in number and longevity of interactions. Integration reflects the affinity for people and the environment, which includes the students' interaction with the college and the colleges' contributions to the students' achievements of their personal goals, as well as integration within a peer group. Learning is also accounted for within socialization processes, which leads to the acquisition of knowledge and other skills. Learning is the students' ability to understand and meet the expectations set by faculty and the department for their performance. Learning can be done through formal or informal means, with formal referring to learning in a classroom, laboratory, seminars and library use and informal from the interactions with peers, faculty and staff outside the classroom.

The socialization processes include students' socialization opportunities which are extra-curricular. For instance, a student that interacts with peers during an extra-curricular activity (design teams, clubs) may be more easily influenced by those peers than faculty in their department. Students' on-campus extra-curricula's are powerful influences on students as they further transmits the institutions values and expectations.

Additionally, there is influence of personality types, with engineers being regarded as realistic, whereas areas as the humanities are regarded as artistic. Like with personality type, different majors seek either intrinsic or extrinsic rewards, with engineering majors seeking primarily extrinsic rewards, such as career orientation.

The outcomes of the model are socialization outcomes, which can be cognitive, such as knowledge and skills, or non-cognitive, such as dispositions and careers. These outcomes influence the individuals' decisions during their pre-college and college experiences through anticipatory socialization, choices an individual makes in anticipation of achieving their goals, usually after college. Style of life and a position in the community system may influence individuals when choosing their careers, and the acquisition of knowledge, both through formal instruction or informal interactions, may influence knowledge outcomes.

Weidman's framework has been used by different authors (Espinosa, 2011, Eagan et al., 2013 and Dawn, 2012), in different capacities, to conduct research on socialization of both undergraduate and graduate socialization.

Focusing on undergraduate socialization, Espinosa, in her 2011 article *Pipelines and Pathways: Women of Color in Undergraduate STEM Majors and the College Experiences That Contribute to Persistence,* used Weidman's framework, along with Carlone and Johnson's (2007) science identity model, to develop a conceptual framework in her quantitative study to understand persistence of women of color in STEM in comparison to white women. Weidman's framework was chosen to model parental socialization and integration in college, and used to inform the quantitative analysis questions on academic and social environments, interpersonal integration and socialization outcomes. Additionally, on a different level, Weidman's framework was used to define institutional variables such as institution type, selectivity and percentage of undergraduates enrolled in STEM majors. Espinosa concluded that women of color who engage in STEM co-curricular activities and the academic community are more likely to persist. Additionally, she notes the importance of not only social peer relationships but also academic ones.

Eagan et al., in their 2013 article *Making a difference in science education: the impact of undergraduate research programs*, used Weidman's framework to inform their variables on students' peer interactions, including interaction of undergraduate students with graduate students, teaching assistants and career intentions. Additionally, Eagan et al looked at the influence of students financial situations by modeling them as external pressures described in Weidman's model (1989) and, like in the article by Espinosa, Weidman's framework was used to define institutional variables such as institution selectivity, size and percentage of undergraduates enrolled in STEM majors. Eagan concluded that students that participate in research activities during their undergraduate degree are more likely to have intentions to pursue a graduate degree in a STEM field in the future.

Dawn, in her 2012 article *Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors*, used Weidman's (1989) framework to develop a conceptual framework of study, including Weidman's model on student characteristics, intrapersonal processes, parental socialization and non-college reference group. In her article, Dawn concluded intrapersonal processes appeared to be the most important to sense of belonging, which has been shown to influence persistence.

In this study Weidman's framework will be used to interpret the results and analyze them, as well as to identify connections between different results in a way that allows for a better understanding of undergraduate socialization and predicting persistence in Aerospace Engineering.

## Research Questions

Current studies do not address the question of why students leave aerospace engineering. Additionally, the studies that address why students choose aerospace engineering were done using small sample sizes. Hence the two research questions this paper will address are:

- Why do students choose aerospace engineering and
- Why do students leave aerospace engineering.

# CHAPTER 2. METHODOLOGY

## Study

Based on the literature review, a questionnaire was compiled from several sources (Grimes et al, 2018, Sheppard et al., 2010, Eris et al., 2005). Survey items covered students' pre-collegiate background, STEM involvement, GPA, transferred credits, extracurriculars, demographics, faculty interaction and other factors that may have influenced their degree choice. Additional questions unique to ISU's (Iowa State University) Department of Aerospace Engineering (AE) were also included, such as students' experience with; AE Learning Communities, freshmen AE courses at ISU, and the AE four-year plan. Questions focused on understanding student motivations for choosing their AE major, and to gain background information on the factors that may have affected their choice to leave their AE major.

After the initial questionnaire was finalized, a pilot study was conducted with six participants from a variety of backgrounds including various age groups, year classifications, and majors (computer science, materials engineering, and aerospace engineering). Their responses to the initial questionnaire were reviewed, and an informal verbal interview was conducted about improvements that could be made to the survey. Changes were made to the survey including the number of choices on multiple choice questions (3 or 5 versus 7), clarification of wording, additional questions (such as if the participants were a transfer student and their previous institution) and rephrasing of several questions that were incorporated into the final questionnaire. After the revisions to the online survey, items that were too complex or required an open-ended answer were placed into an interview protocol, results for which will be discussed in a separate publication. Questions were then organized into sections. The first section contained details about the study and why it was being conducted, a consent statement, and a filter question to ensure that participants had a history with AE. The following sections were: 'background', 'response sorting', 'AERE experiences', 'credits and courses',' demographics', and a follow-up section to opt-in to an in-person interview. Each section was sorted by decreasing difficulty, as well as the questions inside each section. For example, "Why did you choose Aerospace Engineering?" was given before "What is your year classification?". For examples of questions in each section, please see Appendix A.

After the implementation of the suggested changes, the survey was finalized, and all study materials were submitted to the Iowa State University Institutional Review Board and approved for use in this study. The final questionnaire was then converted to an online survey with the Qualtrics Survey tool.

Study participants were identified with the help of the ISU registrar. The selection criteria were as follows:

1. The participant must be enrolled as an undergraduate student at Iowa State University, and
2. Currently declared as an Aerospace Engineering major or were declared as one at any point in the past.

The ISU registrar provided a list of approximately 1,300 university email addresses to students that fit these criteria. Within the Qualtrics Survey tool, participants were emailed a brief statement about the study and a link to complete the survey. Participant enrollment began in the early half of the fall semester, 2018, and was accessible for approximately two weeks. During this time, reminder emails were sent every few days to those that had not completed the survey in its entirety. The response rate was approximately 20% and 245 completed responses were collected.

## Population

Iowa State is a public land-grant and space-grant research university in Ames, Iowa. It is classified as an R1 university for having "very high research activity" in the Carnegie Classification of Institutions of Higher Education. As of Fall 2018, its enrollment was 34,992 students, with 29,621 undergraduate students and 4,774 graduate students. The Aerospace Engineering department has 987 undergraduate students and 111 graduate students. Of those 987 undergraduate students, 89 % are male and 11 % are female and 28% are freshmen, 24% are sophomores, 19% are juniors and 27% are seniors.

## Data

Data was gathered both quantitatively, through multiple choice questions, and qualitatively through open-ended questions integrated into the online survey. For example, one of the multiple choices asked participants about STEM classes, more specifically, "Thinking about STEM courses you are taking or have taken in the past, indicate how often you: Came late to a STEM class", with the possible multiple choice answers being: Not Applicable, Always, Frequently, Occasionally, Rarely and Never. An example of an open-ended question may be "What are your main reasons for leaving Aerospace Engineering?", which was asked to all students who identified as having changed their major from Aerospace Engineering to another major. For other examples of survey questions, please refer to Appendix A. Multiple choice question answers were assigned weights, for example:

Table 1. Example of weights assigned to multiple choice questions

| Answer | Weight |
|---|---|
| Always | 4 |
| Frequently | 3 |
| Occasionally | 2 |
| Rarely | 1 |
| Never | 0 |

For the complete table, please refer to Appendix B. Open-ended questions were coded according to themes found in the literature, as well as themes that emerged from the participant answers.

Coding was done by three reviewers, independently, and three inter-rater reliability tests were done until consensus responses were achieved, after which all responses were compiled. After each inter-rater reliability test, the definitions for each code were modified to better explain the theme it related to.

**Themes**

Several themes emerged from coding of student responses. Some of those themes can be found in previous literature. Table 2 identifies those themes and the reference they were found in:

Table 2. Themes found in participant responses from previous literature

| Theme | Reference |
|---|---|
| Financial | Astin, 1993 |
| Parental Influence | Adelman, 1998 |
| Social Good | Astin, 1993 |
| High School Mentor Influence | Seymour and Hewitt, 1997 |
| College Mentor Influence | Schuman, 1999 |
| Good at math and science | Burtner, 1994 |
| Intrinsic motivation to know | Seymour and Hewitt, 1997 |
| Intrinsic motivation toward accomplishments | Seymour and Hewitt, 1997 |
| Means to a Desired End (Career) | Seymour and Hewitt, 1997 |
| Social Good | Ryan and Deci, 2000 |
| Intrinsic behavioral | Seymour and Hewitt, 1997 |
| Intrinsic psychological | Seymour and Hewitt, 1997 |

Other themes emerged from the participant responses, such as long-term passion for the field of aerospace engineering, the wish to advance aerospace technology and others. For a comprehensive list of themes and their definitions in this publication, as well as an example from participant responses, consult Appendix C. Some students' responses were sorted into more than one theme, for example student 36 "I chose Aerospace Engineering because I was interested by the things that could be done in the discipline. Rockets and airplanes have always been interesting to me, and when I took my first engineering class in high school, I know I wanted to become an aerospace engineer. Also, another big incentive is that the pay is great.". This response was coded into *financial*, *like airplanes*, *like rockets* and *high school classes*. From 245 student responses, 22 unique themes emerged and were assigned 469 times.

# CHAPTER 3. RESULTS

## Why Students Choose Aerospace Engineering

Data collected from participant surveys and analyzed was used to address the research questions and understand why students choose engineering and why students leave engineering.

Figure 2 shows the number of answers for each theme found in participant responses. The most frequent theme found was *long time passion* for the field, where the student indicated as a reason to choose aerospace engineering (AE) their long-term passion for aerospace (aviation, rockets, space) which was not dependent of family influence. This theme is important as this related to the work of Seymour and Hewitt (1997) where the authors mention that students who make uninformed choices most often imagine themselves in “space exploration, flying, or aerospace engineering” and others. Additionally, this theme can be found in the work by Grimes et al. (Grimes et al., 2018), which identifies, as one of the themes for students choosing Aerospace Engineering, “Fascination” and includes “passion, personal interest, dream”. The notion of a long term passion seems to be most prominent in aerospace engineering for the whimsical feelings it invokes in students that grew up dreaming about space exploration or being astronauts. For example, student 17 mentions as a reason to choosing aerospace engineering “It’s been my dream since childhood. Always been fascinated with flight and our ability to conquer the skies, and eventually space.” and student 53 says “Aerospace Engineering always was what I 'dreamed' of doing. Ever since being a little kid, I have been fascinated with machines that fly, watching them and understanding them was what got me interested in aerospace engineering. (…)”.

The second most common theme was *undecided, engineering*, where the student indicated as a reason to choose aerospace engineering that it was the preferred alternative in comparison to other fields of engineering, such as mechanical engineering. Students did not denote a special preference toward AE, but rather an interest in engineering.

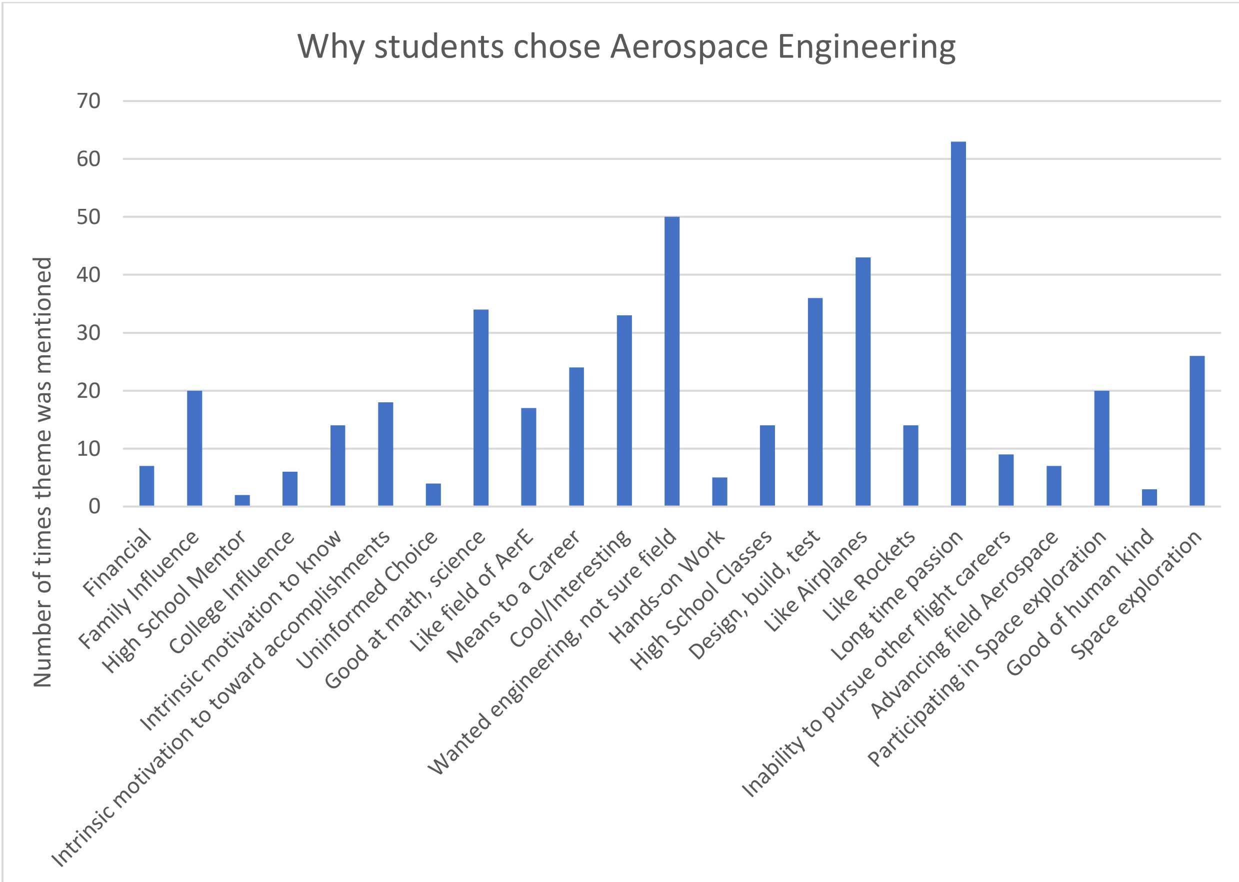


Figure 2. Why students choose Aerospace Engineering

Another common theme was *good at math and science*, where the student indicated as a reason to choose aerospace engineering their aptitude or like for mathematics, physics or other science subjects. Seymour and Hewitt (1997) classify this answer as an uninformed choice, one where the students did not understand the difference between good grades in math and science subjects while in high school with their aptitude for STEM college majors and interest in STEM disciplines, and thus is a logical extension of being good at math and science rather than interest or aptitude. In their study, this one of the top reasons given to choose STEM majors by students who did not persistent in STEM.

Another common theme was identified from student responses mentioning engineering as being “cool” or “interesting”. This theme may be unique to AE by taking on the imagination of students and being fantasized as a “cool” major. Other common themes include *good of human kind*, *intrinsic motivation to know* and *high school class influence*.

The themes identified in student responses show that some reasons for choosing AE overlap with reasons to choose other engineering disciples, such as *financial reasons*, *family influence*, *high school mentor influence* and others. However, it also shows that there are unique reasons for students to choose AE, such as a long-time passion and a desire to participate in space exploration.

Figure 3 shows the reasons why students chose AE by percentage of all students who mentioned the theme.

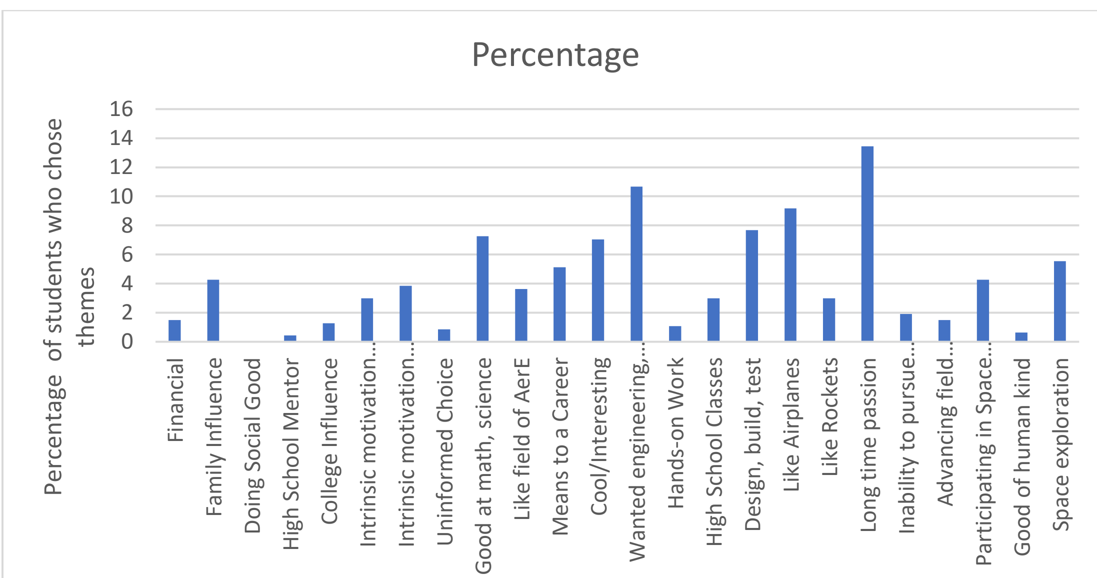


Figure 3. Why students chose Aerospace Engineering, by percentage

In figure 4, there is a comparison between the reasons given by persisters and non-persisters to choose aerospace engineering. Themes are normalized using the formula:

$$Normalized\ Percentage\ of\ students\ per\ theme = Percentage\ of\ students\ per\ theme * \frac{Total\ number\ of\ students}{Total\ number\ of\ replies}$$

Analyses of 22 themes show there are significant differences (p-value<0.05) in two categories, intrinsic motivation toward accomplishments and means to a career. We will also discuss long-time passion (p-value=0.09) and the difference between the group of persisters and non-persisters.

Other themes do not show a significant difference between the group of persisters and non-persisters. Intrinsic motivation toward accomplishments shows a significant difference between persisters and non-persisters, showing that students that mention this as a reason to choose aerospace engineering are more likely to persist in the major. This is in accordance with

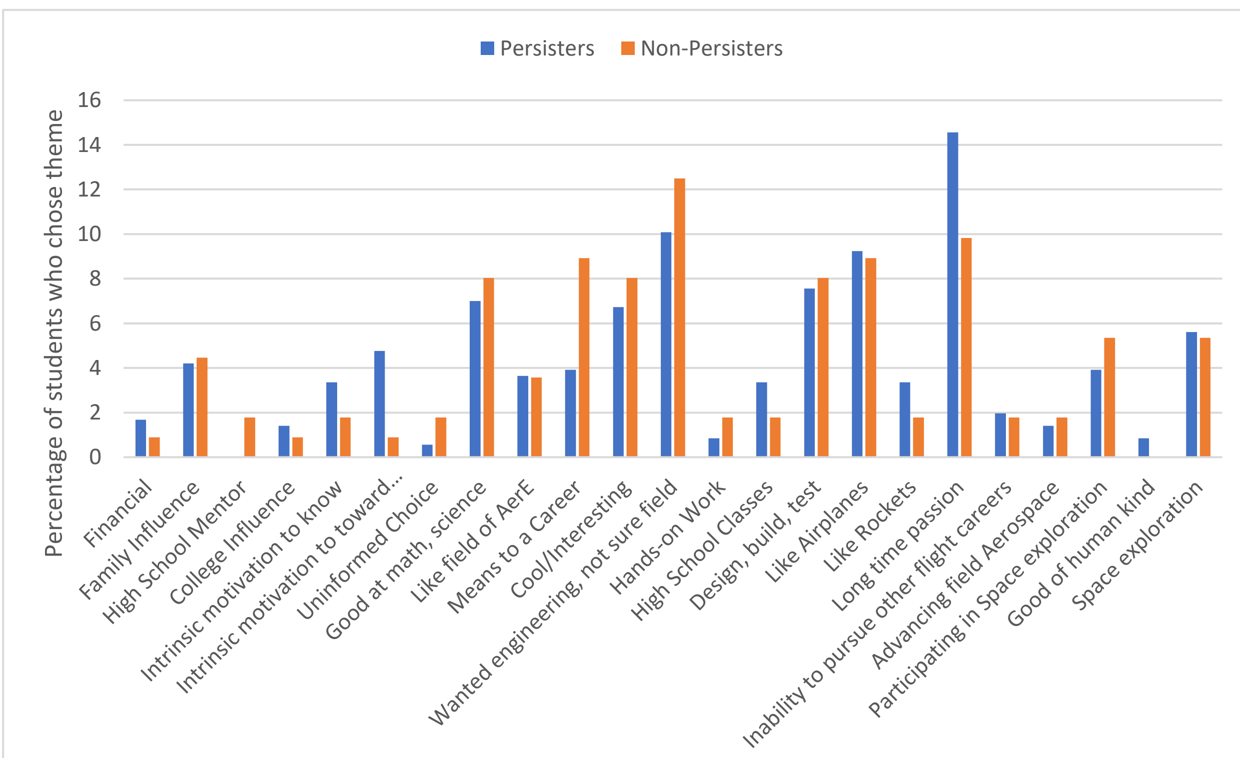


Figure 4. Why students choose Aerospace Engineering, Persisters and Non-Persisters

results from the study performed by Seymour and Hewitt (1997) as well as Sheppard et. al. (2010).

Means to a career also shows a significant difference, with non-persisters indicating this theme as a reason they chose AE more often than persisters. Students indicated wanting to work for NASA and SpaceX as a reason for choosing aerospace engineering. However, the reality of the job market may have presented differently to students after becoming familiar with the field and its job perspectives.

The last category where we see a large difference between the two groups is long-term passion for the field. Student responses coded into this theme spoke about childhood dreams and how aviation played a role in their lives for a long time.

It is interesting to note that all students categorized under *influence of a high school mentor* did not persist in the major, which contradicts findings by Eris et al. (2005). Additionally, all students categorized in *good of human kind* persisted in the major. However, the sample size is too small to make definitive conclusions on this.

**Why Students Leave Aerospace Engineering**

The survey was administered to students who had chosen Aerospace Engineering and included students who, after declaring AE as their major, changed to another major at the same institution. Out of 245 students who answered the survey, 56 students, or 23%, did not persist academically. Respondents that indicated they had changed or planned to change majors unlocked additional questions in the online survey, aimed at understanding their motivations to change majors. These responses were coded and sorted into major themes, both developed from the literature and emergent from students' responses as in the previous section. For a list of all themes and their definitions, consult table 9 in Appendix C. Figure 5 shows the distribution of themes in students' responses.

The most common theme for why students did not persist was related to the AE department. The AE department includes poor advising, poor teaching and disappointment with the program. Poor teaching was the top theme for departmental reasons, with most students indicating they did not feel like professors cared for their education and expressing disappointment with the number of classes taught by teaching assistants rather than professors.

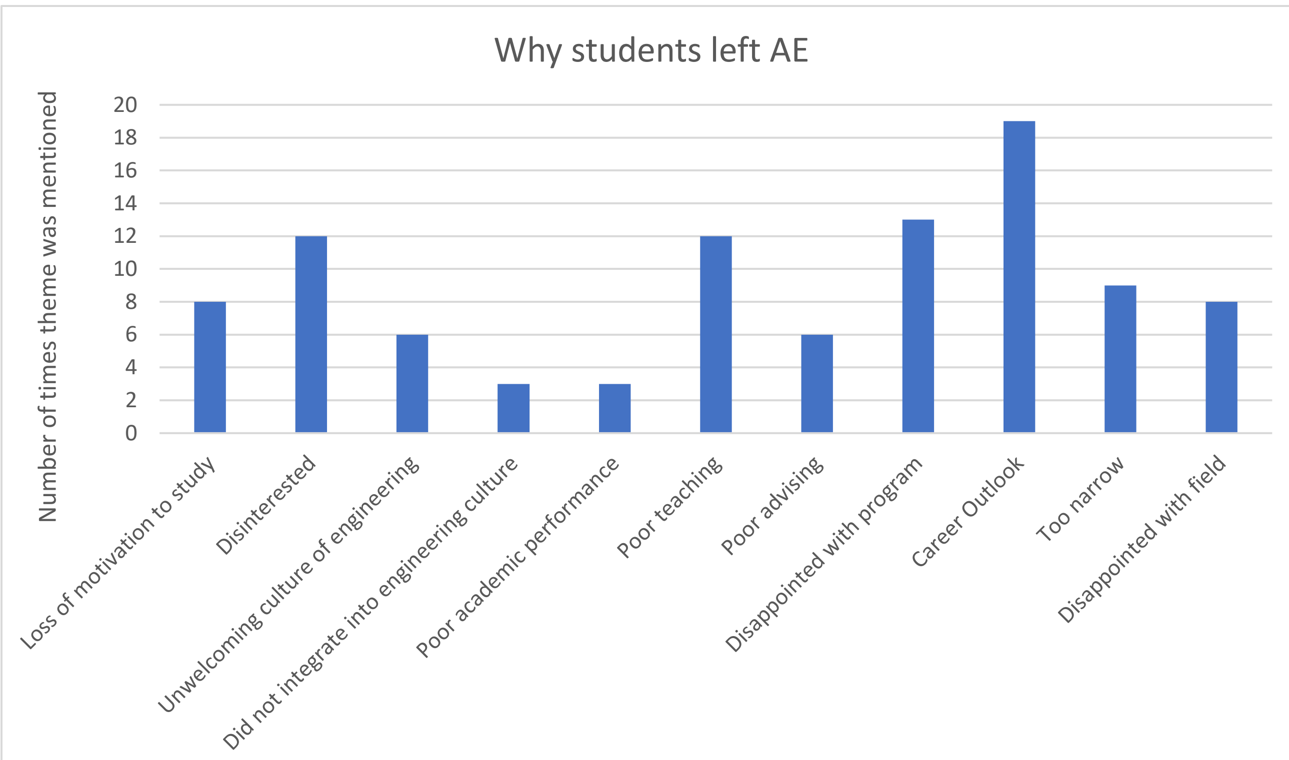


Figure 5. Why students left Aerospace Engineering

The largest unique theme was *career outlook*. Students under this theme expressed their concern with finding jobs after graduation, especially given the perceived lack of job opportunities for new graduates in the aerospace and aviation industry. These students regularly mentioned NASA and SpaceX as companies at which it would be difficult to find employment, while in the aviation industry, Boeing is the most mentioned company. This topic is also correlated with the theme “Too Narrow”, where students mentioned the field of Aerospace Engineering is not broad enough and would prevent students from going into other engineering fields since the knowledge acquired from their degree is very specific to aerospace applications. This connection is made because students indicated that their career outlook was restricted by the perception that AE degrees are not as versatile as other engineering degrees.

The theme *Means to an end*, including a career, was one of the themes in which there was a significant difference between persisters and non-persisters when choosing an AE degree. That difference seems to be explained in the reasons for students to leave aerospace engineering, with many students indicating career outlook as a reason to leave, as well as the field being too narrow. Most students said job prospects for aerospace engineers are limited to aviation and space companies and salaries for aerospace jobs aren’t significantly different from salaries for other engineering jobs.

# CHAPTER 4. WEIDMAN FRAMEWORK

## Background

Weidman's framework input are student background characteristics, which may be predispositions, aptitude, preparation, socio-economic status, diversity and gender. Table 3 shows the background characteristics surveyed.

Table 3. Background characteristics for persisters and non-persisters

| | | Persisters | Non-persisters | All |
|---|---|---|---|---|
| Gender | Male<br>Female | 86%<br>14% | 82%<br>18% | 85%<br>15% |
| Ethnicity | American Indian or Alaskan Native<br>Asian<br>Black<br>Hispanic<br>Native Hawaiian or Pacific Islander<br>White | 1.2%<br>6.3%<br>0%<br>2.5%<br>0%<br>90% | 0%<br>2.2%<br>4.3%<br>0%<br>2.2%<br>91% | 0.98%<br>5.3%<br>0.98%<br>1.96%<br>0.49%<br>90% |
| STEM before ISU | Yes<br>No | 51%<br>49% | 48%<br>52% | 51%<br>49% |
| Transferred credits to ISU | Yes<br>No | 86%<br>14% | 85%<br>15% | 86%<br>14% |
| Average GPA in High School | | 3.677 | 3.736 | 3.706 |
| Family member holds a STEM degree | Yes<br>No | 48%<br>52% | 43%<br>57% | 47%<br>53% |
| First generation college student | Yes<br>No | 11%<br>89% | 10%<br>90% | 11%<br>89% |

Using Weidman's framework, there are no significant statistical differences between persisters and non-persisters gender distribution (within 4%). On the diversity distribution, there are significant differences between the black student population in all-students and the population of students who did not persist. Despite the small sample size (n=2), all Black students who answered the survey will graduate in a different major that is not Aerospace Engineering.

Students' preparation is assessed by looking at the students average High School GPA. High School GPA for persister students is lower than for non-persisters, which indicates this is not a decisive factor in explaining the difference between persisters and non-persisters.

Predispositions is evaluated by looking at the percentage of students whose family members hold a STEM degree and the percentage of first-generation college students'. There seems to be a significant difference between the two groups when looking at percentage of family member who hold a STEM degree, with a difference of 5% between the two groups. However, there is no difference between the two groups on the percentage of family members who are first-generation students. Students' aptitude is evaluated by looking at students prior experiences in STEM, and here the difference between all students and non-persisters is also not significant (3%).

Looking at the background characteristics that construct the Weidman framework, there may be a way to predict persistence in Aerospace Engineering by looking at students whose family members hold a STEM degree. It is also interesting to note that non-persisters had, on average, a higher GPA than persisters, which contradicts other persistence studies.

## Higher Education Experience

Student responses to questions regarding interaction, integration and learning were collected using multiple choice questions. For analysis of student answers, each type of reply was given a weight, which allows for comparison between different groups of students. Table 6 in Appendix B shows the weights given to each question. After the weights were assigned, T-test were performed on the two groups, persister and non-persisters.

Data was not collected that would allow for an investigation on how normative contexts during the higher education experience influence students outcomes and hence persistence in AE, so we will be focusing on socialization processes. Socialization processes are of three natures: interaction, integration and learning.

**Interaction**

Interaction is one of the socialization processes used by Weidman to interpret student's higher education experience. During their academic life, students interact with different people, including their peers, faculty and staff. Among the most frequent interactions are interactions with professors and TA's and with academic advisors. Table 4 shows coefficient responses to questions answered by the students.

Persisters reported interacting with professors during class more often than non-persisters. Persisters also reported interacting with TA's more often during office hours and outside of class or office hours than non-persisters, however, there is no significant difference between the two groups. Non-persisters reported interacting with TA's during class more than persisters, as well as interacting with academic advisers more in all situations.  These results suggest that interaction with academic advisers is a variable that could help predict non-persistence.

Table 4. Interaction factors for persisters versus non-persisters

| | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| *Professors during class* | 1.903 | 1.5962 | 0.052 |
| *Professors during office hours* | 1.303 | 1.0769 | 0.101 |
| *Professors outside of class or office hours* | 1.0424 | 0.8654 | 0.226 |
| *Tas during class* | 1.7515 | 1.8269 | 0.654 |
| *Tas during office hours* | 1.0545 | 0.8824 | 0.221 |
| *TAs outside of class or office hours* | 0.7818 | 0.6346 | 0.294 |

Table 4. Continued

| | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| *Academic advisers during class* | 0.6121 | 0.6923 | 0.518 |
| *Academic advisers during office hours* | 0.8606 | 1.549 | 0 |
| *Academic advisers outside of class or office hours* | 0.8606 | 1.1569 | 0.059 |

**Integration**

Integration reflects the affinity for people and the environment, including integration within a peer group. One of those peer groups is the AE learning community. Participating in extracurricular activities is also part of students' integrations, and these may include design clubs and other university clubs, such as Rocket Team, Electric car team and etc.

Table 5. Integration factors for persisters versus non-persisters

| | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| STEM extracurricular at ISU | 0.7576 | 0.5769 | 0.021 |
| Familiar with AE learning community | 0.9515 | 0.5962 | 0.002 |
| Part of the AE learning community | 0.5212 | 0.5962 | 0.491 |

There is a significant difference between persisters and non-persisters on participation in STEM extracurricular at ISU, with persisters being more likely to participate in extracurricular activities. This shows the importance of integration and agrees with the Weidman framework, which says more opportunities for integration lead to greater socialization.  The learning communities also give students extra opportunities for integration, especially among their peers, which leads to greater socialization. However, it is interesting that although there is a significant difference between students who were familiar with the AE leaning community, there is no significant difference between the two groups when it comes to being part of the AE learning community (currently or in the past).

**Learning**

Students learning was evaluated using the replies to the following questions with answers from Table 6. The same questions were asked to all students about their STEM and non-STEM classes.

Table 6. Commitment to STEM classes versus commitment to non-STEM classes

| ***How likely were you to:*** | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| Came late to a STEM class | 0.9506 | 0.9423 | 0.956 |
| Skipped a STEM class | 0.9815 | 1.1346 | 0.277 |
| Turned in STEM assignments that did not reflect your best work | 1.3642 | 1.4231 | 0.671 |
| Did not complete STEM assignments | 0.6938 | 0.6538 | 0.734 |
| Took good notes during a STEM class lecture | 3.1069 | 2.9615 | 0.324 |
| Were distracted during a STEM lecture (watched Netflix, YouTube, video-games, etc.) | 1.1429 | 1.2692 | 0.43 |
| Came late to a non-STEM class | 1.1829 | 1.1923 | 0.952 |
| Skipped a non-STEM class | 1.2439 | 1.5769 | 0.034 |
| Turned in non-STEM assignments that did not reflect your best work | 1.6196 | 1.5385 | 0.587 |
| Did not complete non-STEM assignments | 0.7853 | 0.7115 | 0.582 |
| Took good notes during a non-STEM class lecture | 2.4321 | 2.2308 | 0.282 |
| Were distracted during a non-STEM lecture (watched Netflix, YouTube, video-games, etc.) | 1.6442 | 1.7692 | 0.488 |

Students were also asked about the quality of professors, teaching assistants and academic advisers.

Table 7. Perceived quality of instruction by professors, TA's and advisers

| | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| Quality of class instruction by professors | 0.6061 | -0.0769 | 0.001 |
| Availability of professors outside of class | 0.7212 | 0.2308 | 0.005 |
| Quality of advising by professors | 0.5576 | -0.0385 | 0.002 |

Table 7. Continued

| | ***Persisters (mean)*** | ***Non-Persisters (mean)*** | ***P-value*** |
|---|---|---|---|
| Quality of class instruction by TAs | 0.4303 | -0.1154 | 0.002 |
| Availability of TAs outside of class | 0.5758 | 0.1538 | 0.011 |
| Quality of advising by TAs | 0.4606 | 0.0385 | 0.006 |
| Availability of academic advisers | 0.9636 | 0.6731 | 0.078 |
| Quality of advising by academic advisers | 0.8182 | 0.3725 | 0.046 |

Table 6 shows students' responses in learning categories. For all students, student responses indicate that students were more committed to STEM classes than NON-STEM classes, with students indicating they were more likely to be distracted, skip, come in late or not complete assignments for Non-Stem classes and indicating they take better notes in Stem classes than non-Stem classes. This distribution is also true for the group of persisters and non-persisters, indicating a similar commitment to STEM classes and Non-stem classes from both students' groups. Despite the differences between the two groups, these are not significant.

Non-persisters report it is more likely that they are late to a STEM class, skip a STEM class or were distracted during a STEM class than persisters. However, this is also true for non-Stem classes. Persisters report it is more likely they did not complete STEM assignments on time, with the same being true for non-Stem classes. Persisters also report taking better notes more frequently in Stem classes than non-persisters, with the same being true for non-Stem classes. Non-persisters also report it is more likely they will turn in Stem assignments that did not reflect their best work, compared to persisters. However, this is not true for Non-Stem, where non-persisters are less likely to turn in assignments that do not reflect their best work.

This difference may show there is a different commitment from non-persisters and persisters, and may help predict retention.

Table 7 shows the perceived quality of class instruction of professors, instructors and advising for academic advisers. In this group there is a significant difference in many questions except availability of academic advisers. This shows that non-persisters perceive the quality of classroom instruction, availability of professors outside of class and quality of advising by professors and TA's to be lower than persisters. Given the significance of the difference between the two groups, these are categories that may be able to predict persistence.

## Where Non-Persisters Go

The Sankey diagram in figure 7 shows students' choices when changing major. Most NP changed majors during their 1st and 3rd semester, with students also changing majors during their 2nd, 4th and 5th semester as seen in figure 6. The majority of NP changed to another engineering major, with the bulk going to mechanical engineering. This supports the evidence provided by themes from student responses that says students that leave aerospace engineering see the field as restrictive in terms of knowledge acquired and prospective career opportunities and would prefer to get an education in a field with a more general scope.

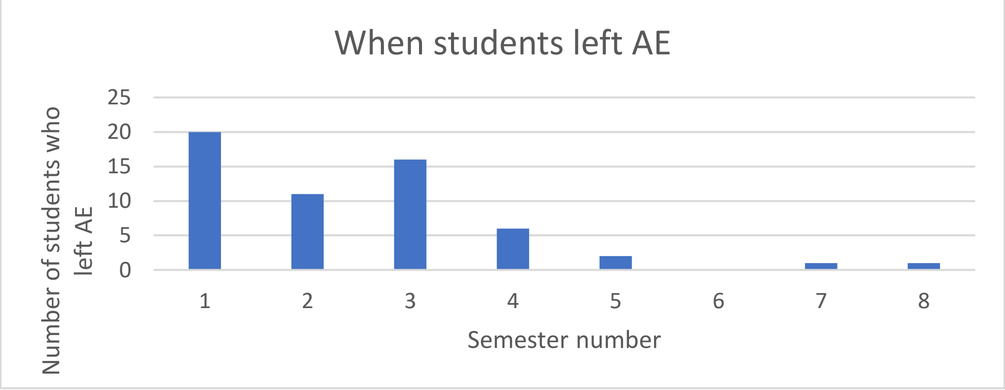


Figure 6. When students left engineering, per semester

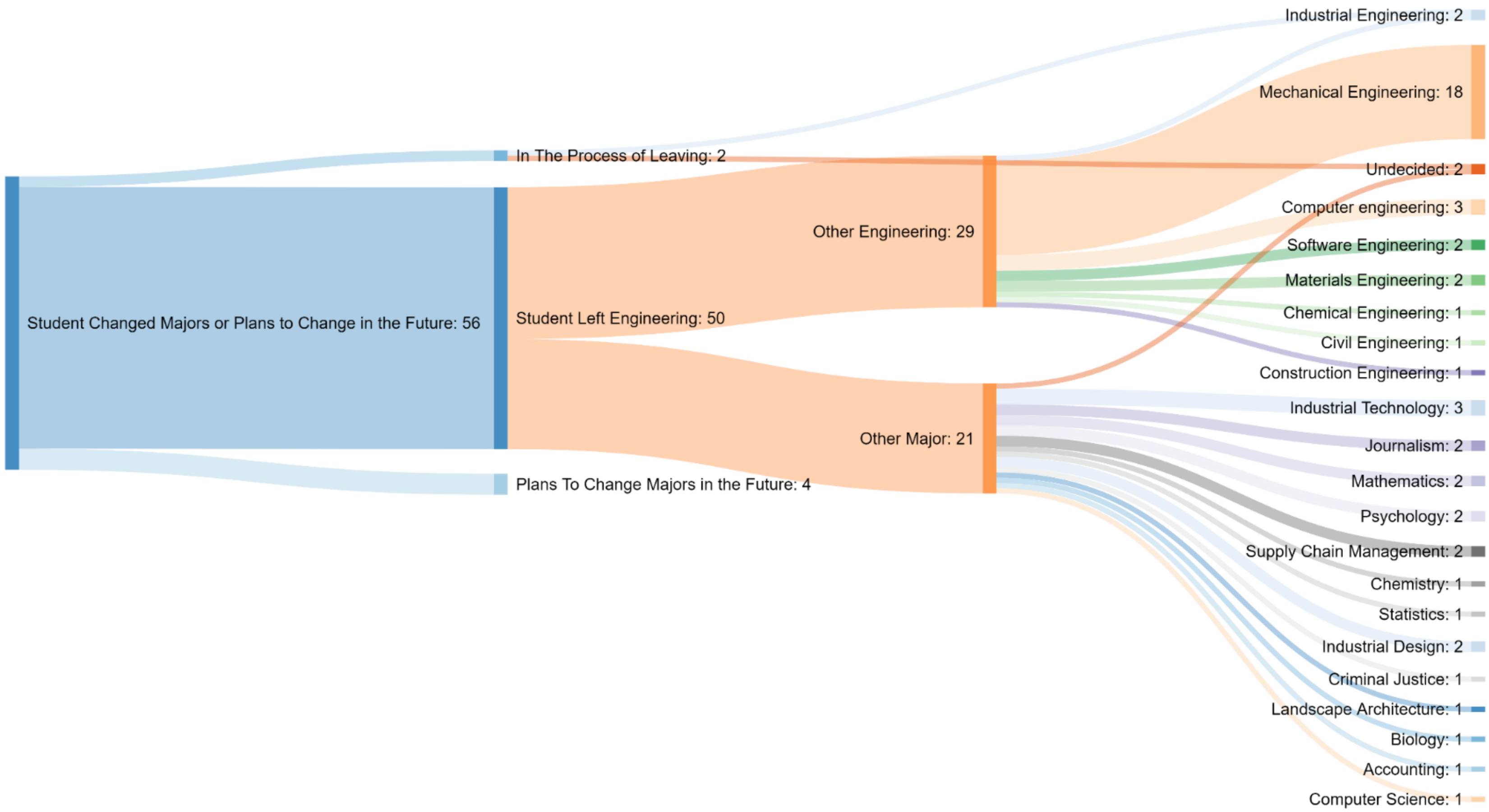


Figure 7. Sankey diagram showing where non-persisters go after changing majors

# CHAPTER 5. CONCLUSIONS

## Implications

The study was undertaken to understand why students choose and leave engineering shows that students are uninformed in their decision to choose aerospace engineering. Students' belief that aerospace engineering is about designing aircrafts and rockets does not correspond to reality. Students should be informed of the reality during the recruitment process and during high school classes that precede engineering majors at universities. Aerospace engineering is spoken about in a whimsical way that entices students with the possibility of participating in space exploration and "building rockets", and students are disappointed to discover that does not correspond to the complete picture. Therefore it is necessary that aerospace engineering programs should seek to inform students on what an aerospace engineer does, and career perspectives showing what percentage of graduates professionally persist in Aerospace Engineering. One other important measure is to provide students with information on the percentage of students who obtain employment in the different areas of aerospace engineering, including the space and aviation industry.

Poor advising and poor teaching are the major reasons given by students for leaving aerospace engineering. These reasons are not unique to aerospace engineering, as it is also referred as a reason for students who leave other fields in engineering (Seymour and Hewitt, 1997, Grimes et al., 2018). Non-persisters are more likely to interact with academic advisers than persisters, perhaps because they are struggling in their courses and are not comfortable reaching out to faculty, which shows the important role that is played by academic advisers in assisting students. Advisors should be trained to encourage students' commitment to the program by showing students they care about their performance and persistence in Aerospace Engineering.

One other implication could be that professors should reach out more to students that are not performing well in their courses, or that are not interacting as much with them, to help boost their persistence.

There are several factors that can help predict non-persisters when we look at their higher education experience. Non-persisters are more likely to skip non-STEM classes, which may be explained by the overall dissatisfaction of non-persisters, not only with their chosen major but with their entire college experience. It would be interesting to investigate this issue further, to understand if the likelihood to disengage from non-major relevant classes continues after the student has changed their major.

On students' part, there needs to be concrete research on what being an aerospace engineering student entails, including the 6-year graduation rate and the percentage of students who find jobs in the students' desired field, including the space industry and aviation industry.

Although Weidman's undergraduate socialization framework takes into account important aspects of the higher education experience as well as student background and anticipated outcomes, it not sufficient to predict persistence in Aerospace Engineering. The challenges presented in understanding persistence in AE may, in part, be due to the themes identified in student responses that are unique to the field, such as long-time passion, which for space exploration and desire to work for NASA and SpaceX, for example. These themes were not identified in other disciplines and need to be taken into account when using a framework to study undergraduate persistence.

## Limitations

There are several limitations that influence the generalization of the conclusions in this study. One of the limitations is that the study was conducted at only one university, and hence there are several factors we are not able to evaluate in combination with the ones in this study, including how university size, research intensity or religious affiliation influences the results. Additionally, the Weidman framework includes contexts as one of the major parts of the higher education experience, and because the study was conducted at only one university, we have no means to compare how the mission, co-curriculum and major fields influence prediction of persistence for aerospace engineering students.

The survey population contained only current students at ISU and did not contain non-persisters that left the university entirely.

From Weidman's framework, one of the background factors that affects undergraduate socialization is diversity. Being that Iowa State is a predominantly white school, with 86% of the students in Aerospace Engineering being white, there is not much ethnic diversity, which might contribute to students persistence or not. However, it is difficult to make conclusions on student persistence based on diversity since the sample population is small and distributed differently from the overall US population.

One other limitation of this study is that the theoretical framework was not used to inform the survey questions, which led to some areas of the Weidman framework not being covered in the survey, either entirely or to an extent that would allow for definite conclusions.

**Conclusions**

Our study aimed to understand why students choose and leave aerospace engineering. Although there are studies on persistence in STEM and other engineering fields, aerospace engineering offers different challenges that proposition different reasons for non-persistence.

In order to understand persistence in aerospace engineering, we applied a survey to current undergraduate students in aerospace engineering and students who were once enrolled in aerospace engineering but had changed majors. We identified several reasons for why students choose and leave aerospace engineering. Most reasons were in agreement with the conclusions from other studies on persistence in engineering. In addition, we found themes that seem to be unique to aerospace engineering, such as the “narrow scope of the field” and “career outlook”, the realization that careers in space and aviation are not as plentiful as students perceived them to be.

There are some significant differences in background characteristics between persisters and non-persisters, one of which is related to students’ predispositions and considers the family’s STEM degrees. However, indicators commonly used by other studies show that higher high school GPA is a good indicator of persistence, which is not the case in this study, where non-persisters entered college with an average GPA higher than persisters. As in other literature (Seymour and Hewitt, 1997, Watson et al., 2015), pre-college factors influence students’ persistence.

Students are also influenced by their higher education experience, where we found significant differences in how students experienced college, which influenced their decision to leave aerospace engineering. Our findings show that students were disappointed with the departmental services provided, including teaching and advising, and that was one of the major reasons for why students left aerospace engineering. Students’ perception of teaching, both by professors and TA’s was that their education was not a priority and they did not feel cared for. Skipping non-STEM classes is also an important factor in predicting persistence in Aerospace Engineering, in which non-persisters were more likely to skip a non-STEM class than persisters. Another major reason was the perceived narrow scope of the field, and its lack of opportunity to pursue a career in aerospace engineering, specifically in space exploration and aviation.

The study shows that not all students are making an informed decision when choosing aerospace engineering, and misconceptions about the degree program and career perspective must be addressed to guarantee students understand the expectations of obtaining a degree in aerospace engineering. There also must be changes in how the department cares for their undergraduate students, especially during their first 3 semesters, when they are most vulnerable to not persist. These changes should be done in advising and teaching, which were the most commonly cited reasons from students to leave the program.

Results suggest interaction with academic advisers is more frequent for non-persisters, which emphasizes the importance of academic advising not only for the students' academic career as well as a factor that can help predict student's non-persistence. For this reason, academic advising should be seen as a fundamental area of improvement to increase student's retention.

Non-persisters should be shown the importance of non-Stem classes in their overall education due to the implied disengagement in non-stem courses.

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# APPENDIX A. QUESTIONNAIRE



English (US)

**Study information**

Welcome to the research study! We are interested in studying student retention in aerospace engineering. The information you share will be of great value in helping to enhance our understanding of student retention and attrition in the aerospace engineering program at Iowa State University. A more detailed explanation about this study and why it is being conducted is provided below if you're interested, if not **please hit the arrow button at the bottom of the page to begin the survey.**

The overall purpose of this study is to enhance understanding of student retention in aerospace engineering. The goals of this study are to find any trends among students that aligns with their choice of major and determine students' main motivations for leaving or staying in the AerE program. This study aims to understand why students prematurely leave the AerE program, and how their motivations and backgrounds compare to students that stay in the AerE program. It is unclear why students leave the AerE program prematurely and what their motivations are or were. It is also unclear if there are common misconceptions or preconceived notions about aerospace engineering among these students that contribute to them leaving, and if their precollegiate backgrounds or other factors influence the likelihood of leaving the program prematurely. By enhancing our understanding of why students leave the AerE program, uncovering any misconceptions, analyzing any trends among students, and making changes or improvements based on your feedback, the AerE department could have a stronger base of students coming in that are more likely to successfully complete the program.

**Click the arrow button below to begin.**

**informed consent**

**Consent Form**

This brief online survey will collect basic demographic information as well as: plans about your major, background information about your extracurriculars, GPA, transferred credits, experiences with your curriculum and faculty and various other similar academic topics.

This survey should take you around **10-15 minutes** to complete, and you will not receive any incentive or compensation for your participation in this survey, you are also not expected to directly benefit from your participation in this study. Your participation is completely voluntary.

This study involves possible minimal risks that include: emotional discomfort from answering sensitive questions or while being audio recorded during the interview. You can decline to answer any question, as well as to stop participating at any time, without any penalty. Incomplete answers will be retained as part of the data for this study. Please be assured that all your responses will be kept completely confidential. Research records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available without your permission. However, it is possible that other people and offices responsible for making sure research is done safely and responsibly will see your information. This includes federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy study records for quality assurance and data analysis. These records may contain private information. De-identified information collected about you during this study may be shared with other researchers or used for future research studies. We will not obtain additional informed consent from you before sharing the de-identified data. Please be assured that your responses will be kept completely confidential. Any digital data will be password protected, and any physical files will be stored in a secure location in a locked filing cabinet where only members of the research team can access the data. Your choice of whether to participate, or to end participation early, will have no effect of any kind on your academic standing or relationships with Aerospace Engineering program faculty, staff, or members of the research team.

If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011. Please print or save a copy of this consent form for your records. If you would like to contact the Principal Investigator of this study to discuss this research, please e-mail Bruce Ciccotosto at bruce@iastate.edu or their supervisor Dr. Benjamin Ahn at bahn@iastate.edu.

By consenting below, you acknowledge that your participation in the study is completely voluntary, you are at least 18 years of age, an undergraduate student at Iowa State University, are currently or were in the past a student in the Aerospace Engineering Undergraduate Program at Iowa State University.

- ○ I consent, begin the study
- ○ I do not consent, I do not wish to participate

**Are you an aere student?**

**Are you currently, or were you ever in the past, declared as an Aerospace Engineering major at Iowa State University?**

- ○ Yes, I am or was an aerospace engineering major
- ○ No, I have never been an aerospace engineering major

**Background**

Why did you choose Aerospace Engineering? Please describe in detail your reasons for choosing aerospace engineering.

Were you involved in any STEM extracurricular activities **PRIOR** to coming to Iowa State University? If so, please explain.

For example, rocketry club, math team

- Yes. (Please explain in the text box.)
- No

Did these STEM extracurriculars **PRIOR** to coming to Iowa State University influence your choice of major? If so, how?

- Yes. (Please explain in the text box.)
- No, it did not influence my choice of major.

Are you or have you been involved in any STEM extracurricular activities **AT** Iowa State University? If so, please explain.

For example, SAE, M2I, Space mining, AIAA, rocketry club, etc

- Yes. (Please explain in the text box.)
- No

Did or do these STEM extracurriculars AT Iowa State University influence your choice of major? If so, how?

- Yes. (Please explain in the text box.)
- No, it did/does not influence my choice of major.

Did you take a gap year between high school and university?

- Yes
- No

Please elaborate about your gap year. For example, what you did, where you traveled, where you worked, etc.

Have you had any working experience related to science, technology, engineering, or math (STEM)?

For example, being a math tutor or SI leader, participating in engineering internship, research position, etc.

- Yes
- No

Please elaborate about your STEM working experience. For example, what you did, where you worked and for how long, etc.

When initially enrolling at Iowa State University, did you transfer any credits from other institutions?

For example, credits from high school AP courses, community college courses, other university courses, etc.

- Yes
- No

How many credits did you transfer to Iowa State University?

Briefly explain the origin of these credits. For example, *"I transferred 4 credits from AP calculus that I took during high school" or "I transferred to ISU after two years at DMACC".*

Are you familiar with aerospace engineering learning communities at Iowa State University?

- Yes
- No

○ Not Sure

A learning community (LC) is a small group of students who take two or more common courses. You can visit this page for more information:
http://www.aere.iastate.edu/undergraduate_program/aere-learning-community/

Were you in the past or are you currently a part of the Aerospace Engineering Learning Community at Iowa State?

○ Yes
○ No
○ Not Sure

What has been your experience with the Aerospace Engineering Learning Community?

If applicable, what did/do you do, and how long had/have you been involved with this community?

Why are you not a part of the Aerospace Engineering Learning Community at Iowa State?

**Response Sorting**

What is your current major? (Press ctrl and click to select multiple.)

- Accounting, B.S.
- Advertising, B.A.
- Aerospace Engineering, B.S.
- Agricultural and Life Sciences Education, B.S.
- Agricultural Biochemistry, B.S.
- Agricultural Business, B.S.
- Agricultural Engineering, B.S.
- Agricultural Studies, B.S.
- Agricultural Systems Technology, B.S.
- Agriculture and Life Sciences Education

You selected "other/not listed" as your major. What is your current major?

What are your plans right now with your declared major?

- a. I plan to stay in Aerospace Engineering.
- b. I plan to stay in my major that is not Aerospace Engineering.
- c. I plan to change majors in the future.
- d. I am in the process of changing majors.
- e. Other. Please Explain:

What are your main reasons for leaving Aerospace Engineering?

How many semesters did you spend as an AerE major before switching? (Counting only fall and spring semesters)

Have you changed your major(s) at Iowa State University at any time? Even if changing from undeclared or undeclared engineering.

- a. Yes, I have changed my major.
- b. No, I have not changed my major.
- c. Other. Please Explain:

What major(s) did you switch from and why? Please explain.

What major(s) do you plan to switch to and why?

How confident were you with your initial declared major?

- Not at all confident
- Little confidence
- Neither
- Somewhat confident
- Very confident

How confident were you with your initial choice of Aerospace Engineering as your major?

- Not at all confident
- Little confidence
- Neither
- Somewhat confident
- Very confident

How confident are you right now with your current choice of major?

- Not at all confident
- Little confidence
- Neither
- Somewhat confident
- Very confident

**AERE experiences**

Thinking about STEM courses you are taking or have taken in the past, indicate how often you:

| | Never | Rarely | Occasionally | Frequently | Always | Not Applicable |
|---|---|---|---|---|---|---|
| Came late to a STEM class | ○ | ○ | ○ | ○ | ○ | ○ |
| Skipped a STEM class | ○ | ○ | ○ | ○ | ○ | ○ |
| Turned in STEM assignments that did not reflect your best work | ○ | ○ | ○ | ○ | ○ | ○ |
| Did not complete STEM assignments | ○ | ○ | ○ | ○ | ○ | ○ |
| Took good notes during a STEM class lecture | ○ | ○ | ○ | ○ | ○ | ○ |
| Were distracted during a STEM lecture (watched Netflix, YouTube, video-games, etc.) | ○ | ○ | ○ | ○ | ○ | ○ |

Thinking about non-STEM courses (e.g., liberal arts, general education, etc.) you are taking or have taken in the past, indicate how often you:

| | Never | Rarely | Occasionally | Frequently | Always | N Appl |
|---|---|---|---|---|---|---|
| Came late to a non-STEM class | ○ | ○ | ○ | ○ | ○ | ( |
| Skipped a non-STEM class | ○ | ○ | ○ | ○ | ○ | ( |
| Turned in non-STEM assignments that did not reflect your best work | ○ | ○ | ○ | ○ | ○ | ( |
| Did not complete non-STEM assignments | ○ | ○ | ○ | ○ | ○ | ( |
| Took good notes during a non-STEM class lecture | ○ | ○ | ○ | ○ | ○ | ( |
| Were distracted during a non-STEM lecture (watched Netflix, YouTube, video-games, etc.) | ○ | ○ | ○ | ○ | ○ | ( |

Please rate your confidence in each of these skills or abilities

| | Not at all confident | Little confidence | Neutral | Somewhat confident | Very confident |
|---|---|---|---|---|---|
| Science ability | ○ | ○ | ○ | ○ | ○ |
| Math ability | ○ | ○ | ○ | ○ | ○ |
| Ability to apply math and science in solving engineering problems | ○ | ○ | ○ | ○ | ○ |
| Ability to solve open ended problems with multiple solutions | ○ | ○ | ○ | ○ | ○ |
| Skills specific to solving aerospace engineering problems | ○ | ○ | ○ | ○ | ○ |

Please rate your satisfaction with each aspect of faculty, teaching assistants (TAs) and advisers in the Aerospace Engineering Department listed below.

| | Very dissatisfied | Dissatisfied | Neither | Satisfied | Very satisfied |
|---|---|---|---|---|---|
| Quality of class instruction by professors | ○ | ○ | ○ | ○ | ○ |
| Availability of professors outside of class | ○ | ○ | ○ | ○ | ○ |
| Quality of advising by professors | ○ | ○ | ○ | ○ | ○ |
| Quality of class instruction by TAs | ○ | ○ | ○ | ○ | ○ |
| | Very dissatisfied | Dissatisfied | Neither | Satisfied | Very satisfied |
| Availability of TAs outside of class | ○ | ○ | ○ | ○ | ○ |
| Quality of advising by TAs | ○ | ○ | ○ | ○ | ○ |
| Availability of academic advisers | ○ | ○ | ○ | ○ | ○ |
| Quality of advising by academic advisers | ○ | ○ | ○ | ○ | ○ |

How often have you interacted with the Aerospace Engineering faculty, teaching assistants and advisers by phone, email, text or chat, or in person?

| | Never | Rarely | Occasionally | Frequently | Always |
|---|---|---|---|---|---|
| Professors during class | ○ | ○ | ○ | ○ | ○ |
| Professors during office hours | ○ | ○ | ○ | ○ | ○ |
| Professors outside of class or office hours | ○ | ○ | ○ | ○ | ○ |

| | Never | Rarely | Occasionally | Frequently | Always |
|---|---|---|---|---|---|
| TAs during class | ○ | ○ | ○ | ○ | ○ |
| TAs during office hours | ○ | ○ | ○ | ○ | ○ |
| | Never | Rarely | Occasionally | Frequently | Always |
| TAs outside of class or office hours | ○ | ○ | ○ | ○ | ○ |
| Academic advisers during class | ○ | ○ | ○ | ○ | ○ |
| Academic advisers during office hours | ○ | ○ | ○ | ○ | ○ |
| Academic advisers outside of class or office hours | ○ | ○ | ○ | ○ | ○ |

## Credits and Courses

How many credits are you currently enrolled in during the Fall 2018 semester?

How many hours in a normal week do you typically spend studying or doing homework outside of class time?

How well are/were you meeting the workload demands (the quantity of material) of your AerE classes?

- ○ Extremely well
- ○ Very well
- ○ Moderately well
- ○ Slightly well
- ○ Not well at all

How do/did the workload demands of your AerE classes compare to your initial expectations?

- ○ Far exceeds expectations
- ○ Exceeds expectations
- ○ Equals expectations
- ○ Short of expectations
- ○ Far short of expectations

The basic program is a set of courses common to all engineering majors and is typically the first year of courses a student will take. These courses are listed below as a reminder for the following questions.

**AER E Basic Program**

| | |
|---|---|
| MATH 165 | Calculus I |
| MATH 166 | Calculus II |
| ENGL 150 | Critical Thinking and Communication |
| ENGL 250 | Written, Oral, Visual, and Electronic Composition |
| PHYS 221 | Introduction to Classical Physics I |
| ENGR 101 | Engineering Orientation |
| LIB 160 | Library Instruction |
| CHEM 167 | General Chemistry for Engineering Students |
| or CHEM 177 | General Chemistry I |
| AER E 160 | Aerospace Engineering Problems With Computer Applications Laboratory |

More information can be found here:
https://www.engineering.iastate.edu/classification/students/basic-program

How well are/were you meeting the workload demands of classes in **the basic program?**

(Workload demands are the quantity of material being taught.)

- Extremely well
- Very well
- Moderately well
- Slightly well
- Not well at all

How do/did the workload demands of classes in **the basic program** compare to your initial expectations?

- Far exceeds expectations
- Exceeds expectations
- Equals expectations
- Short of expectations
- Far short of expectations

How well are/were you meeting the ***pace*** (the rate of new material being taught) of your **AerE** classes?

- Extremely well
- Very well
- Moderately well

- Slightly well
- Not well at all

How does/did the ***pace*** of your **AerE** classes compare to your expectations?

- Far exceeds expectations
- Exceeds expectations
- Equals expectations
- Short of expectations
- Far short of expectations

This table is provided again for your reference on the following questions.

**AER E Basic Program**

| | |
|---|---|
| MATH 165 | Calculus I |
| MATH 166 | Calculus II |
| ENGL 150 | Critical Thinking and Communication |
| ENGL 250 | Written, Oral, Visual, and Electronic Composition |
| PHYS 221 | Introduction to Classical Physics I |
| ENGR 101 | Engineering Orientation |
| LIB 160 | Library Instruction |
| CHEM 167 | General Chemistry for Engineering Students |
| or CHEM 177 | General Chemistry I |
| AER E 160 | Aerospace Engineering Problems With Computer Applications Laboratory |

More information can be found here:
https://www.engineering.iastate.edu/classification/students/basic-program

How well are/were you meeting the ***pace*** of classes in **the basic program?**

(Pace is the rate of new material being taught.)

- Extremely well
- Very well
- Moderately well
- Slightly well
- Not well at all

How does/did the ***pace*** of classes in **the basic program** compare to your expectations?

- Far exceeds expectations
- Exceeds expectations
- Equals expectations
- Short of expectations
- Far short of expectations

## Demographics

What is your year classification by number of credits?

- ○ a. Freshman (Less than 30)
- ○ b. Sophomore (30+)
- ○ c. Junior (60+)
- ○ d. Senior (90+)
- ○ e. Other. Please explain in the text box below.

How many semesters have you been a student at Iowa State University?

(Counting only fall and spring semesters and including the current semester)

What is your race?

- ☐ White
- ☐ Black or African American
- ☐ American Indian or Alaska Native
- ☐ Hispanic or Latino
- ☐ Asian
- ☐ Native Hawaiian or Pacific Islander
- ☐ Other. Please use the text box below.
- ☐ Prefer not to answer

What is your gender?

- ○ Male
- ○ Female
- ○ Prefer to self-describe. Please use the text box below.
- ○ Prefer not to answer

What is your residency status on which your student tuition and fees are based?

- In-state
- Out-of-state
- International
- Other. Please Explain:

What is your cumulative *high school* GPA converted to a 4-point scale? (If not applicable please type "0")

What is your cumulative *college* GPA converted to a 4-point scale? (If not applicable or first-semester student please type "0")

Are you a first-generation college student? (i.e., the first member in your immediate family to attend college)

- Yes
- No

Does anyone in your immediate family (parents, siblings) hold a degree in a STEM field?

- Yes
- No

Who in your immediate family holds a degree in STEM field?

- a. Mother
- b. Father
- c. Brother
- d. Sister
- e. Other. Please explain in the text box.

What degree or degrees do these family members hold?

**Wrap Up and Interview Followup**

Please rate the overall quality of your Aerospace Engineering education so far.

- Very satisfied
- Satisfied
- Neither
- Dissatisfied
- Very dissatisfied

Please rate the overall quality of your Iowa State University experience so far.

- Very satisfied
- Satisfied
- Neither
- Dissatisfied
- Very dissatisfied

Follow-up interviews are also being conducted as part of this study.

Why you should participate in this interview

- This interview allows a way to further share all your experiences in AERE
- This interview helps to tell others about your story of why you chose AERE and chose to leave if applicable.
- Your suggestions about specific courses could be implemented in the future
- Your responses will help reduce misconceptions about what the AERE program will be like for future students
- By collecting your suggestions, and listening to your story about AERE, changes could be made to the AERE program that would encourage future students to stay in the program
- By making changes based on your feedback, the AERE program could have a stronger base of incoming students leading to more graduating aerospace engineers

The interview will cover additional topics on your experiences within the AerE department, your professional and academic motivations, as well as your perceptions of the Aerospace Engineering field in general. The interview will take approximately **30 minutes** of your time, Interviews will be conducted on campus at Howe Hall, at a time and date that is most convenient for you. You will not be asked for an interview after **Saturday, Nov 10, 2018**.

The interview will be audio recorded and later transcribed into text for analysis purposes, any identifying information, such as names, will be censored or assigned a pseudonym during the transcription. Your responses will be kept anonymous, and the audio files will be destroyed after the transcript has been completed. Consenting below does not guarantee you an interview. Your participation is completely voluntary. You can decline to answer any question, as well as to stop participating at any time, without any penalty. Incomplete answers will be retained as part of the data for this study.
Please be assured that all your responses will be kept completely confidential. Please print or save a copy of this consent form for your records. If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office for Responsible Research, Iowa State University, Ames, Iowa 50011.

Would you also like to participate in an audio recorded in-person interview as part of this study?

- ○ Yes, I would like to participate in an interview.
- ○ No, I would not like to participate in an interview.

This survey is anonymous, to schedule the interview with you please provide a way to contact you below (Iowa State email is preferred).

Your method of contact provided below will be kept confidential and only used to schedule the interview or answer your questions about this study.

**Please enter your email in the text box.**

If there is anything else you would like to share as part of this study, please leave a comment below.

Powered by Qualtrics

# APPENDIX B. WEIGHTS

Table 8. Complete answer weights to multiple choice questions

| Type of Answer | Weight |
|---|---|
| Yes | 1 |
| No | 0 |
| Very confident | 2 |
| Somewhat confident | 1 |
| Neutral | 0 |
| Little confidence | -1 |
| Not at all confident | -2 |
| Always | 4 |
| Frequently | 3 |
| Occasionally | 2 |
| Rarely | 1 |
| Never | 0 |
| Very Satisfied | 2 |
| Satisfied | 1 |
| Neither | 0 |
| Dissatisfied | -1 |
| Very Dissatisfied | -2 |
| Extremely Well | 5 |
| Very Well | 4 |
| Moderately well | 3 |
| Slightly well | 2 |
| Not well at all | 1 |
| Far exceeds expectations | 2 |
| Exceeds expectations | 1 |
| Equals expectations | 0 |
| Short of expectations | -1 |
| Far short of expectations | -2 |

# APPENDIX C. THEMES

Table 9. Full list of themes identified from participant responses on why students choose Aerospace Engineering

| Theme | Definition | Sample student quote |
| --- | --- | --- |
| Financial | Student indicated as a reason to choose aerospace engineering the perceived high salaries after graduation. | ”… engineers make good money…” |
| Family Influence | Student indicated as a reason to choose aerospace engineering the direct influence of a parent or grandparent, which may include a family tradition in engineering or a suggestion based on the family member’s past experiences. | “…chose Aerospace Engineering because I grew up with my dad telling stories about his time in the Army and always showed me pictures of him jumping out of airplanes and helicopters.” |
| Mentor Influence High School | Student indicated as a reason to choose aerospace engineering the influence of a high school adviser. | “I was pushed into aerospace engineering but advisors coming out of high school.” |
| High School Classes | Student indicated as a reason to choose aerospace engineering educational experiences while in high school, such as career development classes, pre-college programs and career assessment quizzes. | “I went through a career development class at my high school and engineering was one of my top matches.” |
| College Influence | Student indicated as a reason to choose aerospace engineering experiences while in college, including orientation, aerospace classes and presentations. | “I was interested in it after seeing a presentation given by an associate AerE professor.” |
| Intrinsic motivation to know | Student indicated as a reason to choose aerospace engineering the desire to learn about subjects commonly associated with aerospace engineering, such as aerodynamics, aircraft design and flight vehicles. | “A desire to learn more about aerodynamics and engineering aircraft” |

| | | |
|---|---|---|
| Intrinsic motivation toward accomplishments | Student indicated as a reason to choose aerospace engineering the desire to overcome the challenge brought on by the subjects commonly taught in Aerospace engineering, which are seen as being more challenging than other engineering disciplines. | "I chose to be an aerospace engineer because it was the most challenging engineering discipline in my opinion, and it seemed like the best fit for me." |
| Uninformed Choice | Student indicated an arbitrary reason to choose aerospace engineering. | "Although it was mostly an arbitrary choice to start out in aerospace, I have since decided to stay as an aerospace engineering student, rather than switch to another engineering degree. " |
| Good at math, science | Student indicated as a reason to choose aerospace engineering their aptitude or like for mathematics, physics or other science subjects. | "I loved math and science, especially physics, and wanted to make cool stuff" |
| Interest in Field of Aeronautics or Aerospace | Student indicated as a reason to choose aerospace engineering their interest in the field of Aeronautics or Aerospace. | "The field of study was most appealing to me…" |
| Means to a Desired End (Career) | Student indicated as a reason to choose aerospace engineering the opportunity to work in a desired career, such as space exploration and aviation or working for a specific company such as NASA or SpaceX. | "The field of Aeronautics has captivated my interest since grade school, and being able to design and make a career out of it was my driving factor." |
| Intrinsic psychological | Student indicated as a reason to choose aerospace engineering their perception of the field being "cool" and interesting. | "It was a cool major."<br>"interesting" |
| Undecided, engineering | Student indicated as a reason to choose aerospace engineering that it was the preferred alternative in comparison to other fields of engineering, such as mechanical engineering. Students did not denote a special preference toward aerospace engineering, but rather an interest in engineering. | "I thought it would be a way to study engineering, but thought that mechanical engineering would be too generic and boring, so I thought that it would be more fun" |

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|---|---|---|
| Intrinsic behavioral | Student indicated as a reason to choose aerospace engineering the opportunity for hands-on or practical work or their wish to design, build and test airplanes, space crafts and rockets. | "I chose to be an Aerospace Engineer so that I could be a part of creating the future and help design new aircraft, whether that' space planes military aircraft or drones" |
| Like airplanes | Student indicated as a reason to choose aerospace engineering their fondness for airplanes and aviation. | "The key reason I chose aerospace is that I like spacecraft and airplanes." |
| Like rockets | Student indicated as a reason to choose aerospace engineering their fondness for rockets and other space vehicles | "Always enjoyed reading about rockets and fighter jets." |
| Long term passion | Student indicated as a reason to choose aerospace engineering their long term passion for aerospace (aviation, rockets, space) which was not dependent of family influence. | "It's been my dream since childhood. Always been fascinated with flight and our ability to conquer the skies, and eventually space." |
| Inability to pursue other flight careers | Student indicated as a reason to choose aerospace engineering the inability to pursue other careers in flight, such as becoming a pilot or astronaut. | "I wanted to be a pilot, but decided against it. I turned to aerospace instead since stem was always something I was good at." |
| Advancing field Aerospace | Student indicated as a reason to choose Aerospace Engineering their desire to contribute to the advance of the field of Aerospace Engineering and the technology involved. | "Aerospace technology is some of the coolest and most advanced technology that humans have and continue to create. I want to learn more about it and make contributions to it." |
| Space exploration | Student indicated as a reason to choose aerospace engineering their wish to make contributions to space exploration through aerospace engineering and/or their fondness for space and space exploration. | "I was inspired by the growing number of aerospace companies in the news and the dream of sending humans deeper into space." |
| Good of human kind | Student indicated as a reason to choose aerospace engineering their desire to contribute to the good of human kind through their work in the aerospace industry. | "I want to help people get off of this rock (earth) " |

Table 10. Full list of themes identified from participant responses on why students left Aerospace Engineering

| Theme | Definition | Sample student Quote |
|---|---|---|
| Mismatched expectations | Student indicated as a reason to leave aerospace engineering their loss of motivation to study due to mismatched expectations, especially the amount of hands-on work and design work they would be engaging in. | "I chose to leave engineering because I did not enjoy it. There was too much theory and a ton of math. Not a lot of hands on and applying what we were learning" |
| Disinterested | Student indicated as a reason to leave aerospace engineering the lack of interest in continuing with the program, especially because they did not enjoy, and were no longer interested. Student found a greater interest than aerospace engineering. | "I don't like coding at all" |
| Unwelcoming culture of engineering | Student indicated as a reason to leave aerospace engineering the unwelcoming culture of engineering, including cultural and gender inequality, or a lack of enthusiasm or passion when compared to their peers. | " …and the overall experience for a woman in aerospace engineering Is you are treated as less than. "<br>"I didn't like how business-y it was. Maybe that's the "real world" but it wasn't me. I felt like I didn't belong…" |
| Poor academic performance | Student indicated as a reason to leave aerospace engineering their poor performance in classes. | "not fit for me- too difficult" |
| Poor teaching | Student indicated as a reason to leave aerospace engineering the poor quality of teaching, both from faculty and teaching assistants. Poor quality in this instance refers to the lack of support and care shown by faculty. | " Several aerospace professors I had did not seem to care about teaching, and the courses I had remaining in the program did not interest me as much as the courses in mechanical engineering." |
| Poor advising | Student indicated as a reason to leave aerospace engineering the poor quality of advising, especially the lack or care and encouragement from advisers. | "The staff who deal with freshmen in Aerospace never helped or encouraged my academic success. I was constantly put down and ridiculed, especially by my advisor. I was told my dreams were insignificant and foolish." |

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|---|---|---|
| Disappointed with program | Student indicated as a reason to leave aerospace engineering their disappointment with the curriculum, including classes. | "I really loved my Mat E 273 class and thought that materials application of aerospace is more of my niche. I also was expecting Aerospace Engineering to be more space-focused rather than just airplanes." |
| Career Outlook | Student indicated as a reason to leave aerospace engineering the poor career outlook, especially the perspective of job openings in the area of interest of the student, such as space-related jobs. | "Didn't want to work in HVAC, which is what everyone in aero made it sound like. Only a few people actually get to work in the space sector " |
| Too narrow | Student indicated as a reason to leave aerospace engineering the restrictive nature of the major in terms of choices of subjects to work on during college. | "It was too narrow and I wanted a major I could do anything with." |
| Disappointed with field | Student indicated as a reason to leave aerospace engineering their disappointment with the aerospace field. | "I do not have a passion for it that I was hoping to find. I know I can make the grades and get a job but I don't want to do something for my entire life that I don't have passion for." |

## APPENDIX D. IRB CONSENT FORM

7/25/2019 Study 18-349-00 (IRB)

IOWA STATE UNIVERSITY

**Study**

| | | | |
|---|---|---|---|
| **Study:** | **18-349** | **Sponsor(s):** | |
| **Committee:** | IRB #1 | **Sponsor Id:** | |
| **Category:** | | **Grants:** | |
| **Department:** | Aerospace Engineering | | |
| **Agent Types:** | SBER | **CRO:** | |
| **Title:** | Investigation into Aerospace Student Departure (IASD) | **Year:** | 2018 |
| **2018 Common Rule Date:** | 03/26/2019 | **HIPAA:** | No |
| **Expedited Categories:** | 8c - The remaining research activities are limited to data analysis. | **FDA Study:** | No |

**Comments:** The overall purpose of this study is to enhance understanding of student retention in aerospace engineering at Iowa State University. The goals of this study are to; uncover trends among students that leave AERE prematurely; uncover misconceptions about AERE that contribute to student attrition; record suggestions about specific experiences from students that contributed to their decision to leave the program, and answer the following questions;

1. Are there differences in background, perception, demographics, drive, and experiences between students that leave Iowa State University's Aerospace Engineering program prematurely and those that have continue to complete the program? And if so, what are those differences?
2. What are students' main motivations for leaving or staying in the program?

**Study-Site**

| | | | |
|---|---|---|---|
| **Site(s):** | **00 - Unspecified** | **PI:** | **Ciccotosto, Bruce** |
| **Status:** | Data Analysis Only | **Additional:** | N |
| **Approval:** | June 27, 2019 | **Expiration:** | **N/A** |
| **Initial Approval:** | September 18, 2018 | **Other Expirations:** | Non-Exempt Approval Expiration - 06/25/2022 |
| **Comments:** | | | |

**Study-Site Contacts (4)**

| Name | Role |
|---|---|
| Ahn, Benjamin | Supervising Investigator |
| Bir, Devayan | Research Staff |
| Dhanagopal, Abinayaa | Research Staff |
| Oliveira-Pedro-Dos-Santos, Oliveira-Pedro-Dos-S | Research Staff |

**Events (7)**

| Event | Att | FE | Instance/UDF | Start | Complete | Last Mtg |
|---|---|---|---|---|---|---|
| Modification | 1 | | Personnel Change | 06/27/2019 | 07/16/2019 | 07/16/2019 |
| Modification | 6 | | Transition | 03/26/2019 | 04/02/2019 | 04/02/2019 |
| Modification | 1 | | Personnel Modification | 12/28/2018 | 01/08/2019 | 01/08/2019 |
| Modification | 6 | | | 11/19/2018 | 12/04/2018 | 12/04/2018 |

https://iastate.my.irbmanager.com/Projects/2ca40469-5242-46f5-88a8-aa8fdaf7663c?retUrl=%2FDashboard%2FMyStudies.aspx%3FIsActive%3DTrue 1/2

| Event | Att | FE | Instance/UDF | Start | Complete | Last Mtg |
|---|---|---|---|---|---|---|
| Modification | 6 | | | 10/03/2018 | 10/16/2018 | 10/16/2018 |
| Modification | 6 | | | 09/24/2018 | 10/02/2018 | 10/02/2018 |
| Initial Submission | 6 | | | 08/30/2018 | 10/02/2018 | 10/02/2018 |